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ENHANCED PROPELLANT AND ALTERNATIVE CARTRIDGE CASE DESIGNS

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14. ABSTRACT

The soldier on the battlefield carries a lot of equipment into combat. The ammunition load of 600 or more rounds of 5.56-mm ammunition is a burden to our soldiers. By the use of a higher thermodynamic efficiency and higher combustion pressure, the size of the current 5.56-mm brass cartridge case can be reduced, saving considerable weight and volume. This report describes the enhanced propellant, the novel cartridge case, and the results of ballistic testing.

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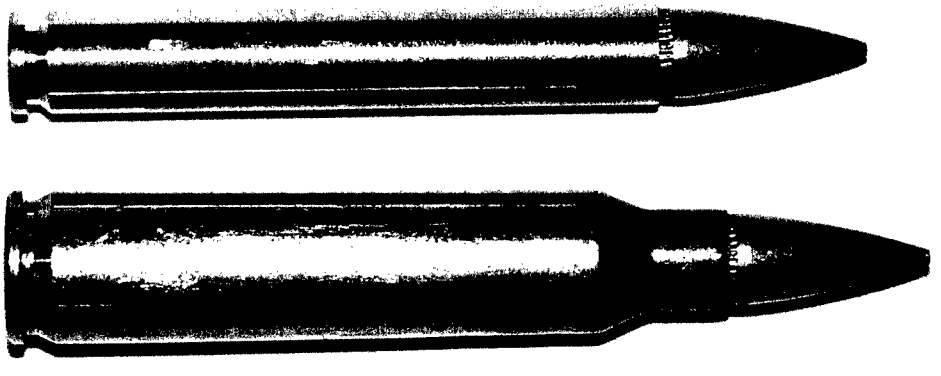
PREFACE

Barrel Heating Reduction

The use of global enhanced propellants in the Global Manufacturing Solutions/Knox Engineering Company (KEC) high efficiency cartridge results in a 75% reduction in barrel heating, permitting the design of a significantly lighter barrel capable of sustaining the current firing schedule.

Global/KEC Cartridge Weight and Volume Reduction with Increased Velocity Compared to the M855 Cartridge

Using 14.0 gr of Global Manufacturing Solutions enhanced propellant in the KEC cartridge [figure follows (with an M855 cartridge for comparison)], an average muzzle velocity of 3,128 fps was achieved firing 62-gr projectiles. The Global/KEC cartridge weighs 28.5% less than the M855 and occupy 49.8% less volume. This does not take into account the significant link weight reduction if a steel push through link were used. Furthermore, the use of a plastic pull-out link would result in a dramatic weight savings versus a steel push-through link. The M27 links used with M855 ammunition weigh 32 gr each. A strong plastic pull-out link for the Global/KEC cartridge would weigh about 7 gr. Nor does this take into account the magazine weight and volume savings resulting from the 49.86% cartridge volume reduction. Six hundred rounds of M855 cartridges in M27 links in three magazines of 6.78 lbs each, weigh a total of 20.35 lb. Six hundred rounds of Global/KEC cartridges in plastic links in two smaller magazines of 6.15 lbs each would weigh a total of 12.30 lbs; a **39.55% weight savings and providing over a 52% volume reduction.** The high efficiency Global/KEC cartridge permits design of shorter, lighter barrels with reduced muzzle blast while delivering M855 ballistics.



INTRODUCTION

This report is a deliverable under Contract DAAE30-03-C-1131, dated 28 July 2003, "Enhanced Propellant and Alternative Cartridge Case Design." The contract was issued in response to the Armaments Research, Development and Engineering (ARDEC), Picatinny, New Jersey BAA DAAE30-03-BAA-400, dated 20 December 2002; the purpose of that BAA was to solicit proposals for component technologies to support the development of a Lightweight Family of Weapons to provide a lethality component of the Objective Force Warrior (OFW) program.

BACKGROUND

The initial focus of the Lightweight Family of Weapons and Ammunition (LFWA), a Joint Service Small Arms Program (JSSAP), was on developing a lightweight machine gun and ammunition. The specific focus was to develop weapon and ammunition technologies that are reproducible en mass, robust, easy to operate and maintain, and reliable under all conditions, while taking up less volume and weighing 30 to 35% less than current systems while maintaining current performance.

SCOPE

The statement of work defines the effort required for the research related to, engineering development of, and testing of the technical feasibility and applicability of an enhanced propellant and an alternative cartridge case design for a lightweight machine gun.

SUMMARY

It was demonstrated that higher thermodynamic efficiency results from employing higher combustion pressure. M855 external ballistics was achieved in an experimental cartridge that, if redesigned into a production cartridge, would result in a cartridge with about 50% of the total volume and about 72% of the total weight of the M855 cartridge alone. Link weight savings and the reduced magazine volume would result in further ammunition weight reductions totaling more than **39% reduced weight** and over **52% reduced volume**.

PROPELLANT TEST RESULTS

Global propellants were developed, formulated, and tested. The purpose of the enhanced propellant research was to study a series of simple propellant formulations and test these to study their ballistic performance. The goals were to:

- Produce more gas per unit volume of propellant
- produce gas pressure profiles so as to enhance energy coupling to the projectile

- reduce total propellant charges to produce equivalent velocities
- reduce heat loss to the barrel

All these goals were met.

Global Manufacturing Solutions propellant codes predicted that velocities exceeding 3200 fps could be achieved with conventional propellants in the KEC high efficiency cartridge. But the codes also predicted that the pressures would be very high. So Global searched the literature and compiled a chart of relative burn rates for most of the commercially available propellants to be used as a guide for testing. Then, tests with a series of conventional off-the-shelf propellants were conducted and the Global predictions were verified. The high velocities could be achieved, but the pressures were very high.

Several Global enhanced propellants were formulated and tested. Various types that produce more gas per unit volume were made. Propellants that vary in burn rate and calorific output were formulated. The enhanced propellants studied provided a multitude of parameters that could be varied to achieve our desired projectile performance goals while at the same time bring the high pressures experienced with pure commercial propellants down to acceptable pressure ranges.

The enhanced propellants produced more gas per unit volume, in some cases produced more energy per grain, less energy per grain, and increased or decreased the rates of reaction.

Impact tests were conducted, and no increased sensitivity was noted as compared with commercial single and double based powders. Some friction tests were performed to establish baselines, but due to the limitations of time and funding, none of the blended propellants were tested to failure. Scanning electron microscopy (SEM) was used to characterize the starting materials and the formulations.

Differential scanning calorimetry (DSC) was used to examine the onset of reaction temperatures, heats of reaction, and relative rates of reaction.

A tabulation of the calorific outputs for some of the propellants studied is shown in the following table. These propellants gave a wide range of parameters to use to tailor the ballistic results.

Samples	Δ H J/gm
G1-5538N	3298.77
G1-2333T	2947.31
G1-2333H	2154.33
G2-2667NX	4340.66
G2-5667NM	4347.25
G2-5552N	3801.47
G2-5538N	4222.08
G2-3839N	3359.41
G2-3048N	4714.02
G2-2333T	3301.9
G2-2333H	3632.81
G2-3459-3	2680.62

Some of the ballistic results for the various Global enhanced propellants are presented in the following table.

Propellant type	Charge (gr)	Projectile (gr)	Muzzle velocity (fps)	Projectile (ft-lbs)	Projectile (E/gr)
G1-2947	15	62	2674	984.164	65.61093
G1-5538	17	62	3126	1345.001	79.11771

These results show significant muzzle velocities with as little as 17 gr of propellant. The next chart shows additional 17-gr load results.

Propellant type	Charge (gr)	Projectile (gr)	Muzzle velocity (fps)	Projectile (ft-lbs)	Projectile (E/gr)
G2-3048	17	62	3310	1507.998	88.70574
G2-3857	17	62	3345	1540.057	90.59161
G2-5538	17	62	3344	1539.137	90.53745
G2-5538	17	62	3394	1585.508	93.26516

These formulations produced superior muzzle velocities when compared to the baseline of 3050 fps and 27 gr of propellant.

The following chart shows the results from a series of Global propellants that produced over 3600 fps with as little as 19 gr of propellant and a 62-gr projectile. It should also be noted that loads as small as 11 to 12 gr produced 2800 + fps with the 62-gr projectile.

Propellant type	Charge (gr)	Projectile (gr)	Muzzle velocity (fps)	Projectile (ft-lbs)	Projectile (E/gr)
G2-2000	15.0	62	2763	1050.767	70.05113
G2-2800	19.0	62	3326	1522.612	80.13746
G2-3030	13.3	62	2875	1137.681	85.5399
G2-3048	17.0	62	3310	1507.998	88.70574
G2-3857	17.0	62	3345	1540.057	90.59161
G2-4000	12.5	62	2755	1044.691	83.57528
G2-5538	17.0	62	3344	1539.137	90.53745
G2-5538	17.0	62	3394	1585.508	93.26516
G2-5552	19.0	62	3599	1782.824	93.83282
G2-5552*	19.0	55	3684	1657.124	87.21703
G2-5552	19.0	62	3604	1787.781	94.09372
G2-5555	11.8	62	2828	1100.787	93.28707
G2-5552B	19.0	62	3662	1845.786	97.14663
G2-5552D	19.0	62	3465	1652.537	89.97562
G2-5552C	19.0	62	3541	1725.824	90.83284
G2-9090	11.1	62	2732	1027.321	92.55142

The following chart shows some of the 19 grain propellant tests in the Global/KEC cartridge with 62 grain projectiles.

*55-gr projectile.

Propellant type	Charge (gr)	Projectile (gr)	Muzzle velocity (fps)	Projectile (ft-lbs)	Projectile (E/gr)
G2-2800	19	62	3326	1522.612	80.13746
G2-5552	19	62	3599	1782.824	93.83282
G2-5552*	19	55	3684	1657.124	87.21703
G2-5552	19	62	3604	1787.781	94.09372
G2-5552D	19	62	3465	1652.537	86.97562
G2-5552B	19	62	3662	1845.786	97.14663
G2-5552C	19	62	3541	1725.824	90.83284

*55-gr projectile.

Some of the 15-gr load propellant tests are shown in the following chart.

Type	Load grains	Projectile grains	V (fps)
G2-3839	15	62	3097
G2-3839	15	62	3211
G2-3839	15	62	3202
Average	**15**	**62**	**3170**
		sigma	**63.37981**

Some of the 14-gr load propellant tests are shown in the following chart.

Type	Load grains	Projectile grains	V (fps)
G2-5667	14	62	3125
G2-5667	14	62	3130
G2-5667	14	62	33129
	14	**62**	**3128**
		sigma	**2.645751**

As can be seen, the M855 cartridge muzzle velocity (3050 fps) was exceeded in the Global/KEC cartridge with only 14 gr of Global enhanced propellant. Additional tests in standard and shortened KEC cartridges produced results with muzzle velocities exceeding baseline with as little as 13.5 gr of Global enhanced propellants.

CONCLUSIONS

The results of the testing demonstrates that much lighter ammunition firing conventional 62-gr projectiles at M855 velocities is possible through the employment of enhanced propellants in small volume, high efficiency cartridges. High efficiency enhanced propellants impose much lower heat loads on barrels permitting the design of weapons with lighter barrels, but permitting significantly heavier firing schedules. Since high efficiency cartridges permit full power cartridge cases to be of significantly smaller diameter, this means much smaller and lighter weapons can, therefore, be provided to the soldier. Given the same combat weight, a smaller and lighter weapon means significantly more ammunition can be carried in the weapon magazine, increasing the weapon firepower.

Enhanced propellants that can be easily tailored to produce varying outputs in a variety of case sizes were demonstrated. It has been shown that M855 velocities can be achieved with 14 gr of propellant in Global Manufacturing Solutions/Knox Engineering Company (KEC) cartridges. And it has been shown that due to the increased efficiency of coupling the energy to the projectile in the Global/KEC cartridge, and the overall reduced quantity of hot gas produced in the system, the end result is significantly less excess thermal energy,and cooler gas imparted to the barrel resulting in less barrel heating. This has significant ramifications for increasing barrel life or firing schedule or reducing barrel weight with also the possibility of eliminating the need for a second barrel altogether. It has also been demonstrated, that these enhanced propellants can be employed in the M855 cartridge itself to produce significantly higher muzzle velocities without the significantly higher pressures that would be encountered by increasing the existing loads.

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